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The interplay of implicit causality, structural heuristics, and anaphor type in ambiguous pronoun resolution

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Abstract

Two visual-world eye-tracking experiments investigating pronoun resolution in Finnish examined the time course of implicit causality information relative to both grammatical role and order-of-mention information.

Experiment 1 showed an effect of implicit causality that appeared at the same time as the first-mention preference. Furthermore, when we counterbalanced the semantic roles of the verbs, we found no effect of grammatical role, suggesting the standard observed subject preference has a large semantic component. Experiment 2 showed that both the personal pronoun *hän* and the demonstrative *tämä* preferred the antecedent consistent with the implicit causality bias; *tämä* was not interpreted as referring to the semantically non-prominent entity. In contrast, structural prominence affected *hän* and *tämä* differently: we found a first-mention preference for *hän*, but a second-mention preference for *tämä*.

The results suggest that semantic implicit causality information has an immediate effect on pronouns resolution and its use is not delayed relative to order-of-mention information. Furthermore, they show that order-of-mention differentially affects different types of anaphoric expressions, but semantic information has the same effect.

Keywords. Implicit causality, Visual-world eye-tracking, pronoun resolution, comprehension, Finnish

Past research has shown that in the absence of disambiguating cues such as gender (e.g., Arnold, Eisenband, Brown-Schmidt, & Trueswell, 2000) people use several sources of information during pronoun resolution (see Garnham, 2001, for an overview). Many studies indicate that people often rely on heuristic strategies that may be related to the structure of the sentence. In particular, people tend to assign an ambiguous pronoun to the subject and/or the first-mentioned referent in the previous clause (e.g., Crawley, Stevenson, & Kleinman, 1990; Frederiksen, 1981; Gernsbacher & Hargreaves, 1988; Järvikivi, Van Gompel, Hyönä, & Bertram, 2005), although this preference can be modulated by the type of pronoun (e.g., personal vs. demonstrative pronoun, Kaiser & Trueswell, 2008). Other researchers have shown that semantic factors also play an important role. In particular, Garvey and Caramazza (1974) noticed that many interpersonal verbs differ in terms of whether they attribute the inferred cause of the event to their subject or object. This is especially the case when stimulus-experiencer and experiencer-stimulus verbs, such as *fear* or *frighten* are followed by the causal connective *because*. Garvey, Caramazza, and Yates (1975) showed that when participants continued sentences such as *John feared/frightened Bill, because he*..., they usually produced continuations consistent with the implicit cause of the described experience. Thus, participants assumed that John feared Bill because there was something about Bill that caused this fear (and something about John with *frighten*), and this influenced whom they took to be the referent of the pronoun. This preference to attribute the cause of an event to a particular entity has been termed the *implicit causality bias*. Ensuing work on implicit causality has often distinguished interpersonal verbs in terms of whether they have the property of attributing the cause to the first (N1) or second (N2) noun, especially in work based on English. Several studies have shown that implicit causality affects the online processing of pronouns as well (e.g., Garnham, Traxler, Oakhill, & Gernsbacher, 1996; Koornneef & Van Berkum, 2006; Stewart, Pickering, & Sanford, 2000).

An issue of particular interest for psycholinguists has been the timing of the implicit causality effect in pronoun resolution. According to the *integration account* (Garnham et al., 1996; Stewart et al., 2000), the effect of implicit causality information does not occur during initial pronoun resolution, but occurs when semantic information in the second clause is integrated with the first. It claims that "there should be no differential activation of the names of the participants in the main event, with differently biased verbs, until it is known whether the subordinate clause is congruent or incongruent with the bias of the verb in the main clause" (Garnham et al., 1996, p. 521). (Note that the predictions of the integration account are not specific to main-subordinate clause order, but see Miltsakaki, 2002 for a different account.) According to a strong version of the integration account, integration of the two clauses does not occur until the end of the second clause (Garnham et al., 1996), though it is possible to assume a weaker version, according to which the processor checks at an earlier point whether implicit causality information is congruent with disambiguating information in the second clause. The integration account assumes that the use of implicit causality information is an inferential process that is delayed relative to the use of other sources of information. Evidence for this comes from a series of probe-recognition experiments by Garnham et al. (2006), who found effects of implicit causality at the end of the sentence, but not immediately after the pronoun. In contrast, immediately after the pronoun, there was an effect of gender on probe recognition, and probes were recognized faster when they corresponded to the first than the second name in the antecedent clause. This suggests that gender and first-mention affect pronoun resolution earlier than implicit causality. Similarly, a self-paced reading study by Stewart et al. (2000) showed no evidence for an early effect of implicit causality. Instead, they found late facilitation for sentences with congruent implicit and explicit causes.

In contrast, the *focusing account* claims that implicit causality information affects the

very earliest stages of pronoun resolution together with other sources of information. Support for this account comes from several probe-recognition studies that have found very early effects of implicit causality information appearing on or shortly after the pronoun (Greene & McKoon, 1995; McDonald & MacWhinney, 1995; McKoon et al., 1993). However, it has been argued that the results of these studies may be due to the probe-recognition task and may not reflect normal language processing (Gordon, Hendrick, & Ledoux Foster, 2000). More recently, several studies using other methods also seem to favor the focusing over the integration account. Koornneef and Van Berkum (2006) found that implicit causality information had an effect shortly after people read a gender-marked pronoun in experiments using self-paced reading and eye-tracking (Koornneef & Van Berkum, 2006), while in an ERP study Van Berkum, Koornneef, Otten and Nieuwland (2007) found a P600 effect appearing 400-700ms after the onset of a gender-marked pronoun which mismatched with the verb bias. Their results suggest that implicit causality information may be used very rapidly when the pronoun is encountered, though it should be noted that these experiments only used pronouns with gender cues, so participants may have relied on gender rather than implicit causality for pronoun interpretation. Perhaps most interesting, using visual-world eye-tracking, Pyykkönen and Järvikivi (2010) showed that implicit causality influenced attention even before listeners encountered the causal conjunction (*because*) preceding the pronoun. In their study implicit causality affected participants' attention to discourse participants immediately after they heard the implicit causality verb. This shows that implicit causality was activated before the pronoun. Recently Cozijn et al. (2011) also observed implicit causality effects in the segment consisting of the connective *because* and the pronoun, which may have occurred either because implicit causality affected activation before the pronoun or while people processed the pronoun. However, it should be noted that finding implicit causality effects before the pronoun do not necessarily imply that it was also immediately

used to resolve it.

Previous studies have mostly looked at the absolute time course of the use of implicit causality information. Although some of these studies suggest that implicit causality has an early effect on pronoun resolution (e.g., Koorneef & Van Berkum, 2006; Van Berkum et al., 2007), these results do not necessarily rule out the integration account if one assumes that integration of semantic information of the second clause with that of the first occurs rapidly, as soon as disambiguating information in the second clause (gender) is encountered. In order to distinguish integration from focusing, we think it is much more informative to study the *relative* time course of implicit causality information during pronoun resolution. The integration account claims that implicit causality information exerts an effect on pronoun resolution during the integration stage, following an earlier processing stage during which various other factors affect the activation of the potential antecedents. Among the many factors that affect pronoun resolution, heuristics such as the first-mention and subject preference are often assumed to have an immediate effect on activation. For example, Gernsbacher (1990) and Gernsbacher and Hargreaves (1988) showed that the first-mentioned entity was more activated than the second-mentioned entity even before or in the absence of a pronoun. As previously mentioned, Garnham et al. (2006) found first-mention effects before implicit causality effects, though it is unclear to what extent the results of their probe-recognition experiments reflect natural sentence processing. In many experiments, the first-mention preference is confounded with the subject preference, because in English, the first-mentioned entity is generally the grammatical subject. However, there is evidence that in Finnish, which allows object before subject word order and therefore allows researchers to disentangle the first-mention and subject preference, the subject preference is very early (Järvikivi et al., 2005; Kaiser & Trueswell, 2008). Thus, if the use of implicit causality information is an inferential process that affects integration processes, whereas the first-

mention and subject preference affect the immediate activation of discourse referents, then implicit causality effects should be delayed relative to effects of first mention and subjecthood. In contrast, if implicit causality affects the very earliest stages of pronoun resolution, then there should be no evidence for a delay.

Until now, most research has tried to contrast the integration and focusing account using sentences that were either disambiguated by gender or semantic plausibility. This may make it difficult to distinguish between the two accounts. On the one hand, because gender or semantics disambiguates the pronoun, they may be such strong resolution cues that any immediate effect of implicit causality is masked, resulting in late effects only. For example, Arnold et al. (2000) observed that the first-mention preference disappeared when the pronoun was gender-unambiguous. On the other hand, disambiguating information may force comprehenders to resolve the pronoun very quickly, and therefore, subsequent integration may occur very rapidly too. This may result in early effects of implicit causality even though they occur during integration. Ambiguous pronoun resolution may be a better test case of the integration account, because there is no disambiguating information which may force comprehenders to resolve the pronoun (Cozijn et al., 2011; McKoon, Greene, & Ratcliff, 1993). As a result, integration should occur later too, so according to the integration account, implicit causality would have a late effect.

Thus, in order to test the two accounts, we used the visual-world eye-tracking method (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) to investigate how comprehenders resolve ambiguous pronouns. In this method, participants listen to short texts containing pronouns, while their eye movements to pictures of the potential antecedents of the pronouns are recorded. Previous research has shown that various factors such as gender disambiguation at the pronoun and discourse focus, order or mention and grammatical role of the potential antecedents of a pronoun all affect fixations to the pictures of the potential antecedents (e.g.,

Arnold et al., 2000; Järvikivi et al., 2005; Kaiser & Trueswell, 2008; Pyykkönen & Järvikivi, 2010). The results of these studies suggest that if people resolve the pronoun as referring to a particular character, the likelihood of looking at this character after the pronoun is increased relative to the likelihood of looking at other characters. We used Finnish as the language of investigation. Finnish does not have gender marking; for example, the personal pronoun *hän* 'he/she' and the demonstrative pronoun *tämä* 'this' can refer to both males and females.

We conducted two visual-world experiments to investigate the time course of implicit causality information relative to the subject and first-mention preference. Järvikivi et al. (2005) showed that both subjecthood and first mention had rapid effects on pronoun resolution in Finnish. The focusing account predicts that the effects of implicit causality on pronoun interpretation should be no later than those of subjecthood and first mention, whereas the integration account suggests that implicit causality effects may be delayed relative to structurally-based effects. Experiment 1 compared the effects of grammatical role and order-of-mention with implicit causality on resolution of the personal pronoun *hän*, while Experiment 2 compared the effects of implicit causality information on the personal pronoun *hän* against the demonstrative pronoun *tämä*.

Experiment 1

Experiment 1 investigated the influence of implicit causality information on the processing of the gender-neutral 3rd-person singular pronoun *hän* in Finnish. First, we investigated the relative time course of implicit causality information compared to order-of-mention (first-mention preference) and grammatical role (subject preference).As shown by the example sentences in Table 1, we tested this by crossing the variables verb bias and word order. The first clause contained either a stimulus-experiencer verb with a bias towards the subject (e.g.,

pelotti 'frightened') or an experiencer-stimulus verb with an object bias (e.g., *pelkäsi*, 'feared'). All the subject and object biased verbs used in the experiment had the same verb root. For example, the verb pair *inhosi* 'despised-3rd person-sg' and *inhotti* 'disgusted-3rd person-sg'), object and subject biasing, respectively, shared the underlying root *inhot-* '>despise/loath' (Finnish verbs are always morphologically complex, so the usual citation form is the 1st infinitive, in this case *inhota* 'to loath/despise').Word order was manipulated by either presenting the first clause in subject-verb-object (SVO) or object-verb-subject (OVS) order. In addition, we added four conditions where the grammatical roles filled by each person/character (e.g., Vladimir Putin and George Bush) were counterbalanced within items, so that each person/character acted as the grammatical subject in half the conditions and as the grammatical object in the other half. The second clause, which was identical in all eight conditions, started with the connective *koska* ' because' immediately followed by the gender-neutral personal pronoun *hän*, which could refer to either person/character.

The integration account suggests that any effects of implicit causality should arise late relative to effects of order-of-mention and grammatical role. In contrast, the focusing account predicts that implicit causality information should have an influence from the earliest point we observe pronoun resolution effects. Because the subject had the semantic role of stimulus and the object the role of experiencer in half the conditions (SVO), whereas the semantic roles were reversed in the other half (OVS), the experiment also allowed us to investigate whether the subject preference is structural, i.e., independent of the semantic roles of the participants in the event. If we observe an overall subject preference, this would indicate that the subject preference is not due to its semantic role. But if there is no overall subject preference, this would suggest that the subject preference has a semantic origin and is not a structural effect. In most studies on anaphor resolution, structural and semantic prominence are confounded, that is, syntactic subjects are almost always prototypical semantic agents and

objects are patients (but see Stevenson, Crawley, & Kleinman, 1994). However, Pyykkönen, Matthews, and Järvikivi (2010) showed that 3-year-old children's pronoun interpretation in English `is sensitive to verb transitivity, i.e., the degree to which the subject and object have prototypical agent and patient like properties (Hopper & Thompson, 1980; Kako, 2006). Moreover, Schumacher, Roberts, and Järvikivi (submitted) showed that agentivity, rather than subjecthood, better predicted the resolution of German third person pronoun *er* and demonstrative *der*. These results suggest that the subject preference may be due to semantic properties.

Method

Participants. Forty-eight students from the University of Turku participated in the experiment. All were native speakers of Finnish and had normal or corrected-to-normal vision. None reported hearing problems.

Materials and design. Thirty-two experimental materials were constructed, consisting of single spoken sentences. The sentences contained a main clause followed by a subordinate clause and appeared in four experimental and four counterbalancing conditions, as shown in Table 1. The main clause mentioned two well-known persons or cartoon characters (e.g., *Vladimir Putin* and *George Bush*) and a location (e.g., *the White House*). The persons and cartoon characters were celebrities, politicians and other prominent figures in the Finnish media. The subject was always in nominative-singular and the object in partitive-singular case. The subordinate clause began with *koska* ‘because’ followed *hän* ‘he/she’; an adverbial phrase (e.g., *kuluneen viikon aikana* ‘during the past week’) that did not bias reference to either interpretation followed the pronoun. Subsequent words also did not strongly bias a particular interpretation of the pronoun.

In order to ensure a strong implicit causality bias either to the subject or the object,

the experimental verbs were selected as follows: 30 intuitively neutral, 30 subject-biased stimulus-experiencer, and 30 object-biased experiencer-stimulus verbs were selected to be tested in a first norming study. The verbs were embedded in sentences of the form *name1 verb name2, because* ... (Garvey & Caramazza, 1974). Each verb was presented in both SVO and OVS order. Two experimental lists were constructed, each containing all 90 verbs, half in SVO and half in OVS order. Participants saw each verb in only one word order. Fifteen participants completed the sentences in a pencil and paper task. Completions were categorized as subject or object referring. Completions in which reference was not to the subject or object (7.0%) and ambiguous completions (2.1%) were excluded. We selected 16 pairs of verbs that shared the same verb stem and had opposing biases (e.g., *pelätä* 'fear' and *pelottaa* 'frighten'; *inhota* 'loath/despise'and *inhottaa* 'disgust'; *hätkähtää* 'startle' and *hätkäyttää* 'startle', with object and subject biases, respectively), with at least 62.5% of completions favoring either the subject or object in the expected direction. Each pair was used twice in the visual-world experiment. Next, we conducted a second norming study in which we put the selected verbs in exactly the same sentences, using both SVO and OVS orders, as in the visual-world experiment (i.e. we used the same persons/characters and added a locative phrase), but cut off after *koska* 'because'. None of the persons/characters mentioned in the sentences appeared more than once. Twenty-four participants completed the sentences. All showed 70% or more completions in the expected direction.

For presentation in the visual-world experiment, the experimental sentences and fillers were read aloud by a male native speaker of Finnish and recorded onto a computer hard disc. In order to control for the time between the offset of the first clause and onset of the conjunction a 600 ms pause was inserted between the offset of the first clause and the onset of the second clause using Praat (Boersma, 1992). This is similar to average clause boundary pauses in natural speech (e.g., Butterworth & Goldman-Eisler, 1979; Van Donzel,

1999).

The subject, object and location were presented as separate 150 X 150 pixel pictures. See Figure 1 for an example. In order to ensure that the participants could not rely on the two pictures of the mentioned protagonists alone, an additional filler picture was added depicting a character that was not mentioned in the experimental sentences. This character was always a well-known person and it was mentioned in half of the filler sentences. The pictures were presented in a quadrangular format. The same four pictures were used within-items. The position of the pictures was counterbalanced between items. The pictures were photographs of well-known persons, depicting the face and part of the upper body, or, in the case of cartoon characters, drawings depicting the entire character. After the eye-tracking experiment, we asked each participant whether they thought there were characters in the experiment that they did not know. All reported knowing all or, in rare cases, most of the characters. In cases where they did not know a character, they knew at least two of the depicted characters, so they were still able to determine who was who. Most of these cases, however, concerned the filler trials.

The 32 experimental materials had eight conditions, defined by word order (SVO vs. OVS) x verb bias (stimulus vs. experiencer) x person/character counterbalancing (e.g., *Putin* first or second mentioned). The materials were counterbalanced across eight lists and randomized; each list began with a filler item and each participant encountered one version of each experimental item, with an equal number of items in all conditions. Each list included 32 filler sentences. Half of the fillers mentioned all three characters depicted in the scenes, the other half mentioned two characters. All fillers mentioned the location depicted in the scene. The fillers mimicked the structure of the experimental items using either subject-object structures or conjoined subjects. However, all fillers used agent-patient verbs and none included pronominal reference to any of the characters. Six participants were randomly

assigned to each list.

Apparatus. An SR Research EYELINK II eye tracker was used to monitor participants' eye movements. A monocular registration with a 500 Hz sampling rate was used. The spatial accuracy was better than 0.5 degrees.

Procedure. Prior to the experiment, the eye tracker was calibrated. Before each trial the calibration was checked by presenting a fixation point in the center of the screen. After the participant had fixated on the fixation point, the pictures appeared on the screen. The auditory presentation of the sentence started 50 ms after the appearance of the pictures and lasted for 12 to 14.5 s. One second after the offset of the sound, the pictures disappeared and the fixation point reappeared. The participants were seated in front of a 20-inch computer screen, at a distance of approximately 65 cm. They were instructed to look at the pictures while listening to the sentences for comprehension. To ensure that the participants attended to the stories and scenes, they were occasionally asked to coherently continue the previously heard sentence using the participants and the location in the sentence. Each participant produced 10 continuations, half of which were in filler and half in experimental trials. Six practice trials preceded the first experimental trial.

In line with the focusing account, we hypothesise a main effect of implicit causality congruence that we expect to arise relatively early on after the pronoun and before any disambiguating information becomes available to the participants. Moreover, if it is semantic rather than grammatical role of the antecedent that guides pronoun resolution, as we hypothesized above, we expect to find no effect of subjecthood. Instead, based on earlier findings (Gernsbacher & Hargreaves, 1988; Järvikivi et al., 2005), we should observe a first-mention preference.

Results

For each 20 ms time frame following the pronoun onset, we determined whether participants

fixated the subject or object character. In 12.9% of the cases, participants were already fixating one of the characters at the pronoun onset. Because such fixations can result from any number of reasons, including but not limited to anticipatory processes, we assume that they do not inform us about pronoun resolution processes. We therefore excluded these trials from further analysis (the excluded trials showed no differences between conditions: $\chi^2(1) < 1$). More generally, such contingent analyses have been recommended to reduce baseline differences and spurious rate effects caused by prior looks in visual world experiments and to ensure that the results are in fact driven by the phenomenon under scrutiny, here pronoun resolution (Heller, Grodner, & Tanenhaus, 2008; Järvikivi et al., 2005). To visualize the results, we plotted the grand average percentage of looks to the characters of interest relative to all looks for each 20ms time segment (therefore the percentages do not add up to 100%): Figure 2 presents the percentage of looks to the critical characters during the semantically neutral region that did not bias the pronoun towards either interpretation (0-1500 ms after pronoun onset) by Implicit Causality Congruence (looks to the character that was congruent with the implicit causality bias, i.e. the stimulus, vs. the character that was incongruent with the bias, i.e. the experiencer) and Grammatical Role (looks to the subject vs. looks to the object character), and Figure 3 for the factors Order-of-mention (looks to the first-mentioned vs. second-mentioned character) and Grammatical Role. For the statistical analyses, we followed the prior literature on pronoun resolution and aggregated these time frames into larger segments of 200 ms (e.g., Arnold et al., 2000; Järvikivi et al., 2005), which allowed us to inspect the relative timecourse of the effects in more detail than larger windows. We analyzed the fixations from 300 ms onwards to allow recognition of the pronoun and programming of saccades (the average offset of the pronoun was at 240 ms), because there were no significant effects during the first 300 ms.

We conducted analyses of variance (ANOVAs) with order-of-mention (1st-mentioned

vs. 2nd-mentioned character), grammatical role (subject vs. object antecedent), and implicit causality congruence (antecedent consistent vs. inconsistent with verb bias) as within-participants and within-items factors (Table 1) and arcsine transformed proportions of fixations on the pictures of the grammatical subject and object as the dependent measure (Table 2). Participant list and item group were included as between-participants and between-items factors (Pollatsek & Well, 1995).

We found a marginal effect of implicit causality congruence in the 900-1100 ms time window, suggesting a preference for antecedents that were consistent with the verb bias over antecedents that were inconsistent with it (Figure 1). This effect became statistically significant in the next two time segments (1100-1300 and 1300-1500 ms). In the 1100-1300 ms segment there was also a main effect of order-of-mention that was significant by items and marginally significant by participants, indicating that participants preferred the first-mentioned to the second-mentioned character (Figure 3). This effect became significant in the last 1300-1500 ms time segment. There was also a grammatical role by order-of-mention interaction in the first analysis window (300-500 ms), which was only marginally significant in the item analysis. This effect was due to people looking less at the first-mentioned object character than any other character. This very early effect did not occur in any other time window and was not observed in our earlier study in Finnish (Järvikivi et al., 2005), suggesting that it may be spurious. Inspection of Figure 3 also suggests that from about 500 ms, participants looked more at the first-mentioned subject than all other potential referents, perhaps suggesting that the first-mentioned subject is particularly salient. However, this conclusion was not supported by statistical analyses, which showed no interaction between order-of-mention and grammatical role in any of the segments ($Fs < 1.70$). Finally, there was no grammatical role effect in any time segment.

Discussion

The results showed an effect of implicit causality on how listeners resolved the Finnish personal pronoun *hän*. The effect appeared well before any disambiguating information was available. Most importantly, this effect appeared at the same time, if not earlier, than the first-mention preference, suggesting that implicit causality information was used as soon as people started resolving the pronoun. This is consistent with the predictions of the focusing account (e.g., Koorneef & Van Berkum, 2006; Van Berkum et al., 2007), but not with those of the integration account (e.g., Garnham et al., 2006; Stewart et al., 2000). Notably, we found no effect of grammatical role. When we counterbalanced the semantic roles of the verbs, the subject preference found previously for *hän* (Järvikivi et al., 2005; Kaiser and Trueswell, 2008) was lost. This suggests that what has traditionally been taken to be an effect of grammatical role is (at least partly) semantic in nature.

Experiment 2

Experiment 2 investigated whether the early effects of implicit causality that we observed with the personal pronoun *hän* in Experiment 1 also occur with a different anaphoric expression, the demonstrative pronoun *tämä*. We therefore compared the processing of *hän* and *tämä* using the same sentences as in Experiment 1. As shown in Table 3, the first clause always had SVO order and contained either a stimulus-experiencer or experiencer-stimulus verb. The second clause started with *koska* 'because' followed by either *hän* or *tämä*. Four additional conditions were added to counterbalance the grammatical role filled by each person/character. In order to reduce the number of conditions, we did not use OVS order.

Tämä can be a demonstrative pronoun, denoting close proximity, or a discourse deictic, roughly equivalent to English *this*, e.g., *This is Peter; Peter had stolen a biscuit* (Kaiser & Trueswell, 2008). *Tämä* can also be used as a pronoun to refer to male and female

referents that have been most recently mentioned out of two or more possible antecedents (Hakulinen & Karlsson, 1988), or to less prominent, non-subject, antecedents in the discourse (Halmari, 1996; Kaiser, 2000; Kaiser & Trueswell, 2008), often signaling a topic shift or a shift in focus (e.g., Hedberg, 2000). This is consistent with linguistic theories that claim that demonstrative pronouns signal referents that are less accessible than personal pronouns do (e.g., Ariel, 1990; Gundel et al., 1993). If the use of *tämä* indeed signifies that its antecedent may be inaccessible or less available, it should preferentially be interpreted as referring to the object, because it is less prominent than the subject due to the first-mention preference (but not due to the subject preference, given that Experiment 1 showed no grammatical role effects). In other words, the results should be different from those with *hän* in Experiment 1, which showed a first-mention preference. Furthermore, if semantic prominence has a similar effect, there should also be a preference to interpret *tämä* as referring to a semantically less prominent entity, the entity that is inconsistent with the implicit causality bias. In other words, whereas *hän* should refer to entity that is most prominent due to both first mention and due to implicit causality information (as in Experiment 1), preferences for *tämä* should be reversed. Assuming that we observe such reversed prominence effects with *tämä*, the question is whether the use of implicit causality information is delayed relative to that of the first-mention preference.

However, research by Kaiser and Trueswell (2008) suggests that preferences for *hän* and *tämä* are not complementary. Whereas *hän* was strongly biased towards subject antecedents, *tämä* showed very little preference for the object. Instead, *tämä* exhibited a strong second-mention preference. They argued that this supported the form-based hypothesis: Each anaphoric expression is sensitive to different factors. Hence, the effect of implicit causality on *tämä* may not be the reverse of its effect on *hän* (as hypothesized above); instead both may preferentially be interpreted as congruent with the implicit causality

bias. Thus, the question would be whether the time course of implicit causality is similar that of the first-mention preference for *hän* and the second-mention preference for *tämä*.

Method

Participants. Forty-eight new participants from the same population as in Experiment 1 took part.

Materials and design. We used the same 32 experimental materials as in Experiment 1, but in order to reduce the number of conditions only SVO word order was used in the first clause (see Table 3). The pictures and fillers items were the same as in Experiment 1 and the materials were prepared in the same way.

Apparatus and procedure. The apparatus and procedure were the same as in Experiment 1.

We hypothesize that if *tämä* is interpreted as referring to less prominent, non-subject or last mentioned, antecedents, we should observe more looks to the second-mentioned object than the first-mentioned subject antecedent with *tämä* (Kaiser & Trueswell, 2008). That is, we expect to find an interaction between order-of-mention (1st vs. 2nd-mention) and type of pronoun (*hän* vs. *tämä*). Moreover, if *tämä* is also interpreted as referring to the semantically less salient antecedent, we should observe a reversed implicit causality effect for *tämä* compared to *hän*, showing as an interaction between type of pronoun and implicit causality congruence. In other words, we should find more looks to the *semantic experiencer* than the *theme* for *tama*. However, if implicit causality bias is independent of pronoun status (personal vs. demonstrative), we expect to find a main effect of implicit causality congruence, as in Experiment 1.

Results

As in Experiment 1, in some cases (14.8%) participants were already fixating one of the characters at the pronoun onset. We excluded these trials from further analysis because, as we note above, such fixations can result from any number of reasons, including but not limited to anticipatory processes and we thus assume that they do not inform us about pronoun resolution processes (as for Experiment 1, the excluded trials showed no differences between conditions: $\chi^2(1) < 1$). we excluded trials on which participants fixated either of the critical characters at pronoun onset (14.8%; there were no differences between conditions: $\chi^2(1) < 1$). Figure 4 presents the time course of the effects within the semantically neutral region (300-1500 ms after pronoun onset) for the factors Pronoun (*hän* vs. *tämä*) and Congruency (looks to the character that was congruent with the implicit causality bias, i.e. the stimulus, vs. the character that was incongruent with the bias, i.e. the experiencer) and Figure 5 for the factors Pronoun and Order-of-Mention (looks to first vs. second-mentioned character) for each 20 ms time frame following the pronoun onset. As before, we analyzed the fixations from 300 ms onwards to allow recognition of the pronoun and programming of saccades (the average offset of the pronoun was at 240 ms) and because there were no significant effects during the first 300 ms.

We conducted ANOVAs on arcsine transformed proportions of fixations on the subject and object character with order-of-mention (1st-mentioned vs. 2nd-mentioned character), pronoun (*hän* vs. *tämä*), and implicit causality congruence (antecedent consistent vs. inconsistent with the verb bias) as within-participants and within-items factors (Table 4).

The results showed a main effect of implicit causality bias already in the 300-500 ms segment by participants that became significant for both by participant and by item tests in the next two time segments (500-700 and 700-900 ms), showing an overall preference for antecedents that were consistent with the implicit causality bias over antecedents that were

not. In the fourth time segment (900-1100 ms) the effect was significant by items, but not by participants. The early main effects of implicit causality congruence in combination with the absence of a pronoun by congruence interaction indicated that the effect of implicit causality was consistent for both *hän* (Experiment) and *tämä*.

However, we did find an interaction between the type of pronoun and congruence later in the 1100-1300 and 1300-1500 ms segments. This late interaction indicated that the effect of implicit causality in these segments was modulated by the type of pronoun. Separate ANOVAs for the two pronouns showed that in these late time windows the effect of congruence was not significant for *hän* (all Fs < 1), whereas a significant effect of congruence in both of these time segments was observed for *tämä* [1100-1300: $F1(1, 40)=5.29$, $p < .05$; $F2(1, 24)=5.65$, $p < .05$; 1300-1500: $F1(1, 40)=6.24$, $p < .05$; $F2(1, 24)=6.67$, $p < .05$], showing a preference for antecedents that were consistent with the implicit causality bias. Thus, there was no evidence that *tämä* is biased towards semantically non-prominent entities.

There was also a marginally significant interaction between order-of-mention and pronoun starting 500-700 ms from the pronoun onset which became significant in the 700-900 ms segment. Separate analyses for the pronouns in the 700-900 ms time segment showed a 1st-mention preference for *hän* that was marginally significant by participants [$F1(1, 40)=3.84$, $p = .057$] but not by items [$F2(1, 24)=1.71$, $p = .20$]. For *tämä* there was a marginal 2nd-mention preference [$F1(1, 40)=2.98$, $p = .092$; $F2(1, 24)=3.64$, $p = .068$]. In the next 900-1100 ms segment there was a significant order-of-mention by pronoun interaction. Further analyses showed a marginal second-mention preference for *tämä* [$F1(1, 40)=2.87$, $p = .098$; $F2(1, 24)=3.18$, $p = .087$], whereas for *hän* there was a marginal 1st-mention preference by participants that was not significant by items [$F1(1, 40)=2.93$, $p = .094$; $F2(1, 24)=1.83$, $p = .188$]. This interaction was significant also in the last 1300-1500 ms window, showing a

significant first-mention preference for *hän* [$F1(1, 40)=4.09$, $p = .050$; $F2(1, 24)=3.94$, $p = .059$], but no preference for tämä [$F1(1, 40)=1.01$, $p = .322$; $F2 < 1$].

Discussion

Experiment 2 showed no evidence that the implicit causality effect was delayed relative to the order-of-mention effect for *hän* and *tämä*, consistent with the results from Experiment 1. The earliest significant effect of implicit causality for both by participant and by item tests occurred at 500-700 ms, whereas the earliest interaction between order-of-mention and pronoun, which indicated that *hän* and *tämä* were differently affected by order of mention, occurred at 700-900 ms. These results are consistent with the focusing account (e.g., Koorneef & Van Berkum, 2006; Van Berkum et al., 2007), but do not support the integration account (e.g., Garnham et al., 2006; Stewart et al., 2000)

The implicit causality effect did not interact with type of pronoun; both *hän* and *tämä* preferred the entity consistent with the implicit causality bias, so was no evidence that *tämä* was interpreted as referring to the semantically non-prominent entity. In fact, in the later time windows (1100-1500 ms) the preference for the entity consistent with the implicit causality bias was stronger with *tämä* than *hän*. One possible explanation for this might be that *tämä* is a more marked, less common pronoun than *hän*, and that this more strongly encourages people to search for the semantically most plausible antecedent.

In contrast, the interaction between order-of-mention and type of pronoun (500-900 ms) suggests that structural prominence affected *hän* and *tämä* in opposite ways. Similar to Experiment 1, there was a first-mention preference for *hän*, though the effect was less pronounced (perhaps because of the smaller number of observations in Experiment 2). In contrast, *tämä* exhibited a preference for the second-mentioned entity.

General Discussion

We set out to investigate the time course of implicit causality information in ambiguous pronoun resolution during spoken language comprehension. Our visual-world eye-tracking experiments showed consistent effects of implicit causality. In Experiment 1, the implicit causality effect occurred at the same time or even earlier than the first-mention preference, which had a similar time course as in our previous study in Finnish (Järvikivi et al., 2005). Similarly, in Experiment 2, the implicit causality effect was slightly earlier than the first-mention effect on *hän* and *tämä* (indicated by the order-of-mention by pronoun interaction). In both experiments, the implicit causality effects occurred during the semantically neutral region, before the main verb. Thus, the use of implicit causality was not delayed until the end of the subordinate clause, as predicted by the strong version of the clausal integration account (Garnham et al., 1996). Furthermore, there was no evidence for a delay in the use of implicit causality information relative to other information, as suggested by a weaker version of the integration account. The results are in accordance to the focusing account, which follows the assumption that implicit causality has an immediate effect on pronoun resolution. Implicit causality information should have an effect at the earliest point at which pronoun interpretation preferences start to arise.

In contrast to many previous studies, the early implicit causality effects that we observed were found before language comprehenders encountered disambiguating information such as gender or plausibility information. If a pronoun is disambiguated, the disambiguation may force rapid integration of the first and second clause, so implicit causality biases may be found early even if they occur during integration. But because our pronouns were ambiguous, this account does not explain the current results.

However, it should be noted that, although the implicit causality effects were clearly not delayed relative to order-of-mention information, they did not occur during the

presentation of the pronoun, but appeared from around 500 ms after the pronoun onset. The most obvious reason for this is that it takes some time for listeners to determine an antecedent for the pronoun and before this is reflected in eye-movement behavior. Also, compared to unambiguous - e.g., gender-marked - pronouns, where grammatical information may force immediate resolution, ambiguous pronoun resolution may take more time to complete, because it is a more knowledge-based process, that relies on multiple sources of information, none of which provides a categorical disambiguation (Frank, Koppen, Noordman, & Vonk, 2007).

Experiment 1, which counterbalanced the semantic roles of the grammatical subject and object, showed no overall effect of grammatical role. Thus, when we used stimulus-experiencer rather than agent-patient verbs and controlled for semantic roles, the effect of grammatical role disappeared. This suggests that the standard subject preference reported in a number of studies may in fact have a large semantic component. The present results are in line with other recent studies. Kehler, Kertz, Rohde, and Elman's (2008) off-line studies suggest that the subject preference may arise as a consequence of a more general quest for discourse-based coherence relations in pronoun interpretation. More importantly, Pyykkönen et al. (2010) showed that even at the age of three, English children's pronoun interpretation was modulated by the degree of verb transitivity (Hopper & Thompson, 1980; Kako, 2006), i.e., whether the subject and object had many agent and patient-like properties (as with *hit*) or only a few (as with *see*; see also Rose, 2005). Together with these studies, our results indicate that semantic prominence is an important component of referent salience affecting anaphor resolution.

Finally, Experiment 2 showed a dissociation between order-of-mention vs. implicit causality information and the type of anaphor: Whereas the demonstrative *tämä* preferred the second-mentioned antecedent, as predicted by theories that assume that demonstrative

pronouns refer to less prominent entities (e.g., Ariel, 1990; Givón, 1983; Gundel et al., 1993), it did not show a preference for the semantically less prominent antecedent. In fact, although both *hän* and *tämä* showed a preference for the antecedent consistent with implicit causality information in early time windows. In later time windows (1100-1500 ms), this preference lasted longer for *tämä* than for *hän*, perhaps because the use of a more marked, less common pronoun may more strongly encourage people to search for the most plausible antecedent. The different effects of order-of-mention and implicit causality information on *hän* and *tämä* are consistent with Kaiser and Trueswell (2008), who argued that rather than being affected by the same determinants of salience, people use different sources of information in assigning an antecedent to different anaphoric expressions. In other words, in their view, a further dimension is needed whereby different anaphoric expressions may be sensitive to various sources of information to a different degree. Our results are in line with this interpretation: Whereas order-of-mention affected *hän* and *tämä* in opposite ways (in line with Kaiser and Trueswell, 2008), our results showed that *hän* and *tämä* both preferred antecedents consistent with implicit causality (though the preference was somewhat stronger with *tämä*).

To summarize, the present results showed that the effect of implicit causality is not delayed relative to that of order-of-mention information in ambiguous pronoun resolution. Rather, the results suggest that people start using semantic information as soon as they attempt to resolve an ambiguous pronoun. Furthermore, in line with other recent studies, we showed that implicit causality was used before people had enough information to integrate the two clauses. Finally, because the implicit causality effects occurred before the pronoun was disambiguated, our results are difficult to interpret as reflecting early integration. Therefore, our results are inconsistent with the integration account and consistent with the focusing account of implicit causality in pronoun resolution.

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Figure Captions

Figure 1. An example picture used in Experiment 1 and 2. The picture corresponds to the example materials in Table 1 and 3.

Figure 2. Percentage of looks (out of all looks) to subject and object characters in Experiment 1 as a function of implicit causality congruence, i.e., whether the implicit causality bias was congruent or incongruent with the grammatical role of the character, and time (300-1500 ms) after pronoun onset.

Figure 3. Percentage of looks (out of all looks) to subject and object characters in Experiment 1 as a function of order-of-mention1st-mentioned, 2nd-mentioned) and time (300-1500 ms) after pronoun onset.

Figure 4. Percentage of looks (out of all looks) to characters with congruent and incongruent grammatical role and implicit causality bias in Experiment 2 as a function of the pronoun (*hän*, *tämä*) and time (300-1500 ms) after pronoun onset.

Figure 5. Percentage of looks (out of all looks) to 1st-mentioned and 2nd-mentioned characters in Experiment 2 as a function of the pronoun (*hän*, *tämä*) and time (300-1500 ms) after pronoun onset.

Figure1

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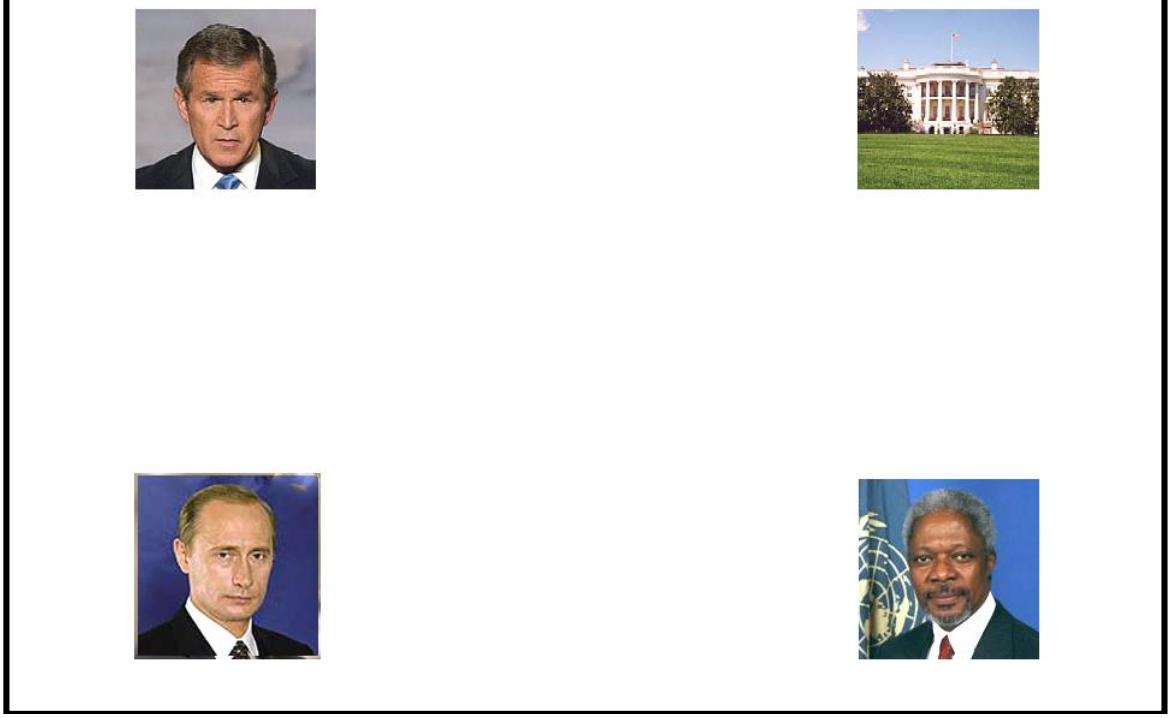

Figure2

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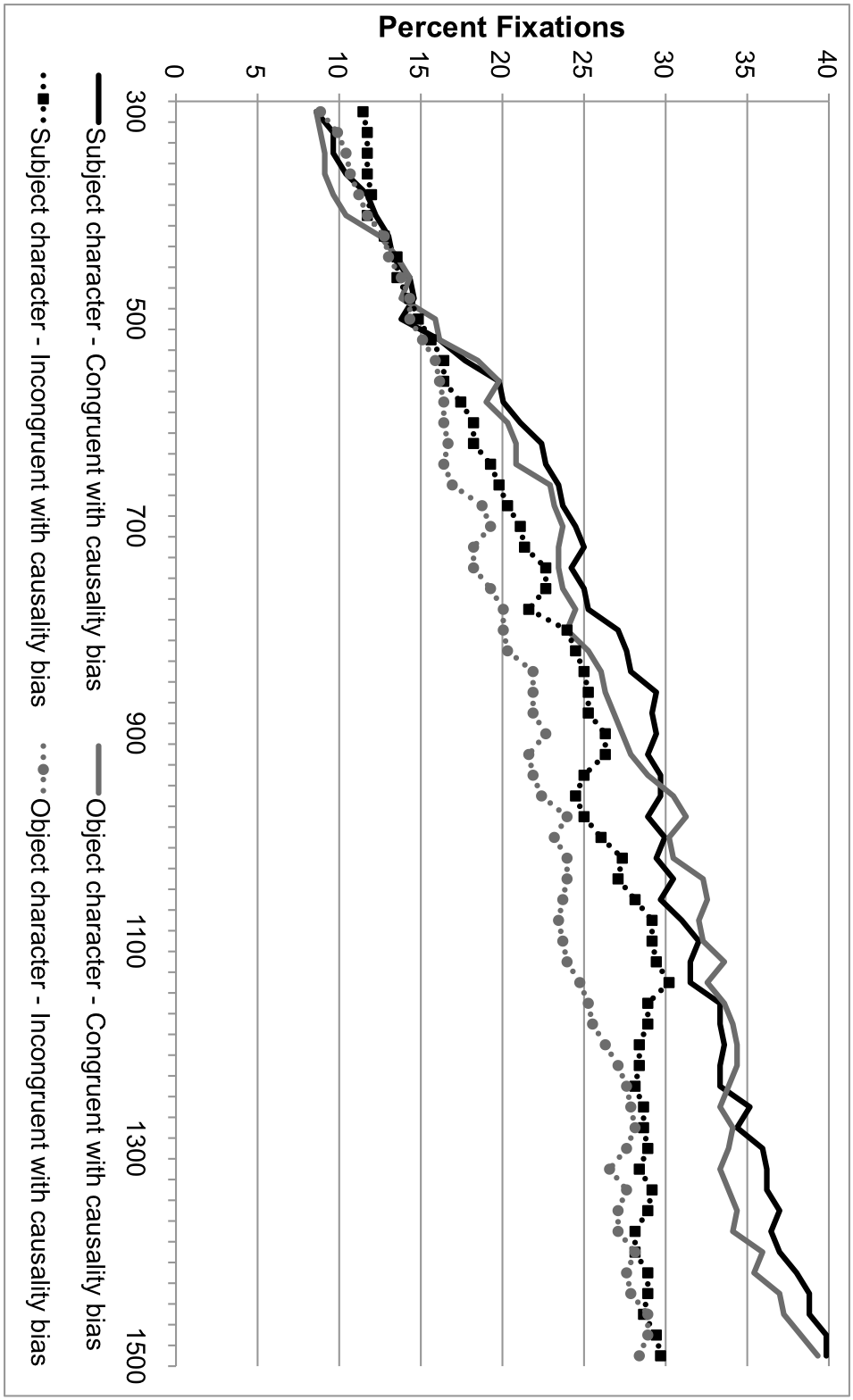

Figure3

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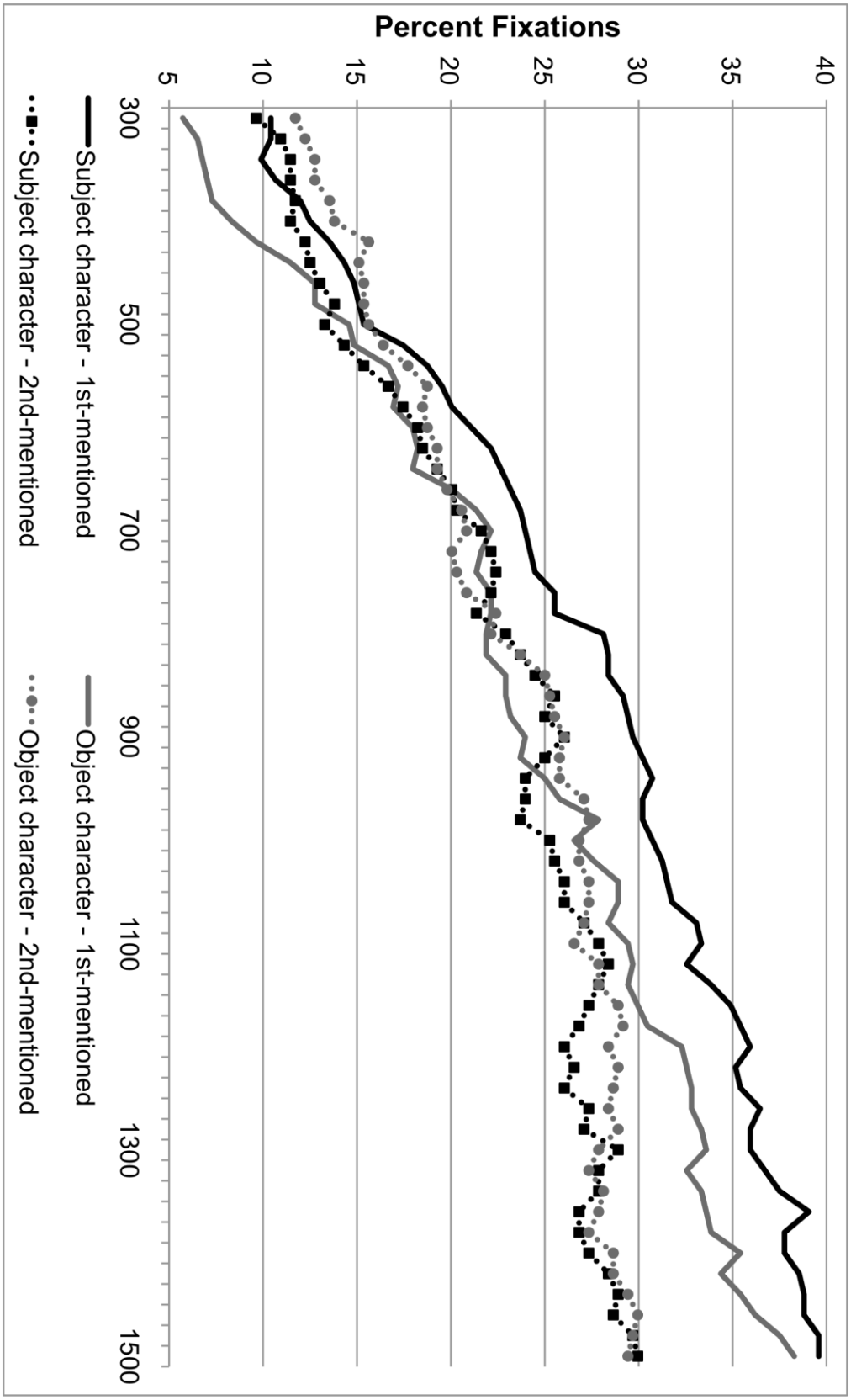

Figure4

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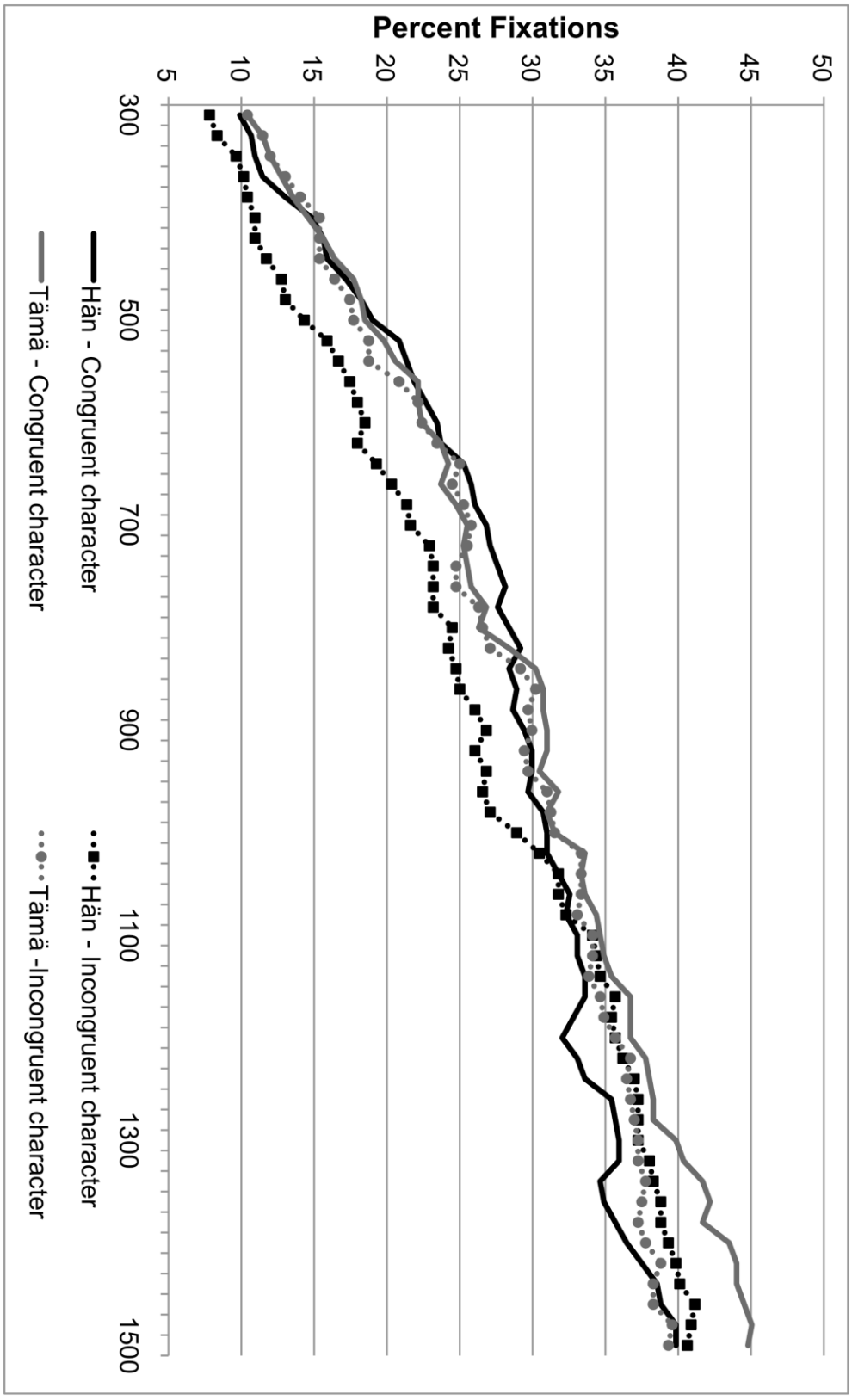

Figure5

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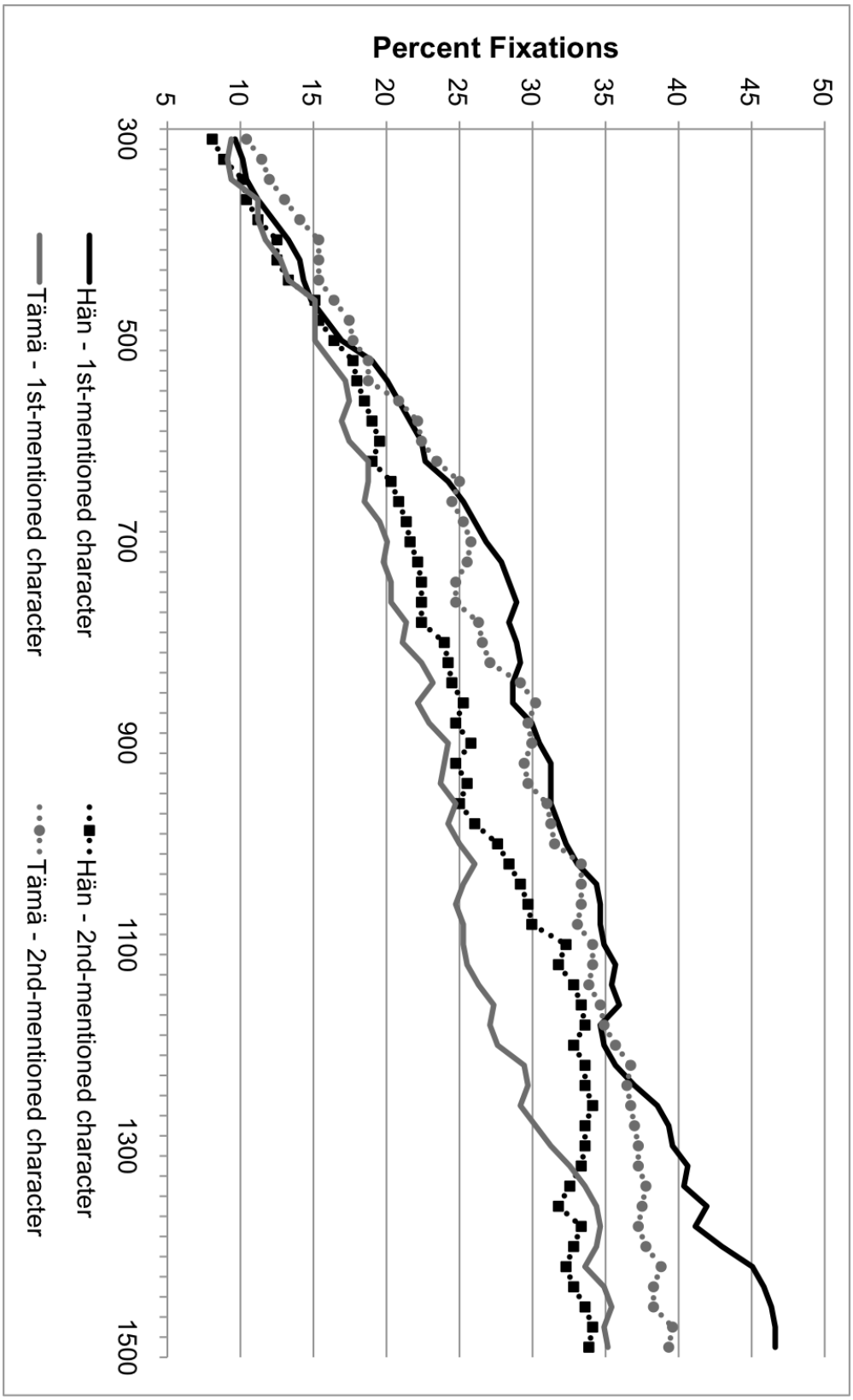

Table 1. Examples of the materials in Experiment 1. The conditions resulted from crossing the variables word order (main clause in SVO or OVS word order) and verb bias (subject-biased or object-biased verb in the main clause, i.e., an experiencer-stimulus or stimulus-experiencer verb). In addition, four conditions were added where the grammatical roles filled by each person/character were counterbalanced within items so that each person/character acted as the grammatical subject in half the conditions and as the grammatical object in the other half, resulting in eight versions of each item. Implicit causality congruence refers to which character the implicit causality bias of the verb in the main clause is consistent with. Abbreviations: nom = nominative case; ptv = partitive case; sub = subject; obj = object.

Main clause	**Subordinate clause**	**Grammatical Role**	**Order-of-mention**	**Implicit causality congruency**
SVO: *Vladimir Putin pelotti George Bushia Valkoisessa talossa* "Vladimir Putin (`nom-sub`) frightened George Bush (`ptv-obj`) at the White House"	*koska **hän** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because he had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Subject: Putin Object: Bush	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Putin Incongruent: Bush
SVO: *Vladimir Putin pelkäsi George Bushia Valkoisessa talossa* "Vladimir Putin (`nom-sub`) feared George Bush (`ptv-obj`) at the White House"	*koska **hän** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because he had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Subject: Putin Object: Bush	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Bush Incongruent: Putin
OVS: *Vladimir Putinia pelotti George Bush Valkoisessa talossa* "Vladimir Putin (`ptv-obj`) frightened George Bush (`nom-sub`) at the White House"	*koska **hän** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because he had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Subject: Bush Object: Putin	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Bush Incongruent: Putin
OVS: *Vladimir Putinia pelkäsi George Bush Valkoisessa talossa* "Vladimir Putin (`ptv-obj`) feared George Bush (`nom-sub`) at the White House"	*koska **hän** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because he had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Subject: Bush Object: Putin	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Putin Incongruent: Bush

Table 2. Results from the time course analyses in Experiment 1 for six consecutive 200 ms time segments starting 300 ms after the pronoun onset.

	Time Segment After Pronoun Onset (ms)											
	300-500		**500-700**		**700-900**		**900-1100**		**1100-1300**		**1300-1500**	
Main Effects	***F1*** (*p*) ***MSe***	***F2*** (*p*) ***MSe***	***F1*** (*p*) ***MSe***	***F2*** (*p*) ***MSe***	***F1*** (*p*) ***MSe***	***F2*** (*p*) ***MSe***	***F1*** (*p*) ***MSe***	***F2*** (*p*) ***MSe***	***F1*** (*p*) ***MSe***	***F2*** (*p*) ***MSe***	***F1*** (*p*) ***MSe***	***F2*** (*p*) ***MSe***
(1) Grammatical Role	< 1	< 1	< 1	< 1	1.91 (.17) .001	< 1	< 1	< 1	< 1	< 1	< 1	< 1
(2) Order-of-mention	2.03 (.16) .001	2.92 (.10) † .001	< 1	< 1	< 1	< 1	1.02 (.32) .003	1.36 (.26) .003	3.03 (.09) † .004	4.38 (.05) * .004	6.57 (.014) * .025	7.95 (..009) ** .005
(3) Implicit causality Congruence	< 1	< 1	2.45 (.13) .001	3.02 (.09) † .002	3.39 (.07) † .002	2.54 (.12) .003	3.74 (.06) † .003	3.65 (.07) † .004	5.24 (.03) * .003	4.12 (.05) * .005	6.56 (.014) * .004	6.73 (.016) * .006
Interactions												
(1) x (2)	4.55 (.04) * .001	2.95 (.099) † .002	1.52 (.23) .001	< 1	< 1	< 1	1.33 (.26) .002	1.70 (.21) .003	< 1	1.12 (.30) .003	< 1	< 1
(1) x (3)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
(2) x (3)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	2.18 (.15) .001	1.31 (.26) .003
3-way	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1

Notes: $F1$: $df = (1, 40)$; $F2$: $df = (1, 24)$; † $p < .1$; * $p < .05$

Table 3. Examples of the materials in Experiment 2. As in Experiment 1, we counterbalanced the grammatical roles of two persons/characters in the first clause, resulting in eight versions of each item. Implicit causality congruence refers to with which character in the main clause the implicit causality bias of the verb is consistent. Abbreviations: nom = nominative case; ptv = partitive case; sub = subject; obj = object.

Main clause	**Subordinate clause**	**Pronoun**	**Order-of-mention**	**Implicit causality congruence**
SVO: *Vladimir Putin pelotti George Bushia Valkoisessa talossa* "Vladimir Putin (`nom-sub`) frightened George Bush (`ptv-obj`) at the White House"	*koska **hän** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because he had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Hän 's/he'	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Putin Incongruent: Bush
SVO: *Vladimir Putin pelkäsi George Bushia Valkoisessa talossa* "Vladimir Putin (`nom-sub`) feared George Bush (`ptv-obj`) at the White House"	*koska **hän** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because he had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Hän 's/he'	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Bush Incongruent: Putin
SVO: *Vladimir Putin pelkäsi George Bushia Valkoisessa talossa* "Vladimir Putin (`nom-sub`) frightened George Bush (`ptv-obj`) at the White House"	*koska **tämä** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because this had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Tämä 'this'	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Putin Incongruent: Bush
SVO: *Vladimir Putin pelkäsi George Bushia Valkoisessa talossa* "Vladimir Putin (`nom-sub`) feared George Bush (`ptv-obj`) at the White House"	*koska **tämä** oli kuluneen viikon aikana antanut useaan otteeseen ymmärtää, ettei maiden Irakin suhteissa olisi näkemyseroja* "because this had during the past week given many times the impression that there would be no differences of opinion concerning the countries' relations with Iraq"	Tämä 'this'	1st mentioned: Putin 2nd mentioned: Bush	Congruent: Bush Incongruent: Putin

Table 4. Results from the time course analyses in Experiment 2 for six consecutive 200 ms time segments starting 300 ms after the pronoun onset.

	Time Segment After Pronoun Onset (ms)											
	300-500		**500-700**		**700-900**		**900-1100**		**1100-1300**		**1300-1500**	
Main Effects	***F1*** (p) MS_e	***F2*** (p) MS_e	***F1*** (p) MS_e	***F2*** (p) MS_e	***F1*** (p) MS_e	***F2*** (p) MS_e	***F1*** (p) MS_e	***F2*** (p) MS_e	***F1*** (p) MS_e	***F2*** (p) MS_e	***F1*** (p) MS_e	***F2*** (p) MS_e
(1) Order-of-mention	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
(2) Pronoun	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1.93 (.18) .001	1.88 (.19) .001	< 1	< 1
(3) Implicit causality Congruence	2.37 (.13) .002	4.33 (.048) * .002	5.24 (.023) * .003	8.21 (.009) ** .003	5.29 (.03) * .003	8.23 (.008) ** .003	2.49 (.12) .006	4.62(.04) * .005	1.17 (.29) .002	1.88 (.18) .002	2.06 (.16) .009	2.35 (.14) .014
Interactions												
(1) x (2)	< 1	< 1	3.90 (.055)† .002	2.25 (.065) † .006	5.91 (.02) * .001	4.99 (.04) * .005	4.97 (.04) * .007	4.97 (.04) * 172.070	3.53 (.07) † .001	2.40 (.14) .003	4.42 (.04) * .007	2.97 (.097) † .015
(1) x (3)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
(2) x (3)	< 1	< 1	< 1	< 1	< 1	< 1	1.27 (.27) .004	1.28 (.27) .007	4.90 (.03) * .001	4.00 (.057) † .002	5.60 (.02) * .007	4.67 (.04) * .012
3-way	1.07 (.31) .001	1.48 (.24) .002	3.16 (.08) † .002	2.47 (.13) .003	2.40 (.13) .002	2.53 (.13) .004	2.80 (.096) † .003	3.21(.08) † .004	2.31 (.14) .001	4.14 (.053) † .001	1.82 (.18) .003	1.73 (.20) .004

Notes: $F1$: $df = (1, 40)$; $F2$: $df = (1, 24)$; † $p < .1$; * $p < .05$; ** $p < .01$.